Resolving the conflict between environmental damage and agricultural viability on less favoured areas

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Abstract—**Production linked supports are paid for agriculture in less favoured areas (LFA) in Finland in order to maintain agricultural production and farms. The CAP reform increased the importance of LFA payments and other payments which are still partly coupled to production. We evaluate if any significant environmental damage can be avoided without risking maintenance agricultural production in less favoured areas. We also evaluate the relative effectiveness of alternative policy measures to decrease nutrient surplus, promote biodiversity, and maintain production and farm income. The policy options evaluated are full decoupling, fertiliser tax, both combined and explicit payments for reduced nutrient surpluses. The impacts of the options are compared to the baseline assuming milk quota abolition and continuation of production linked CAP beef premia.**

Sector model results suggest that decoupling of certain degree would improve the effectiveness of targeted agri-environmental support measures, and in some cases considerable reduction in nutrient surplus is possible with relatively minor reduction in agricultural production and farm income. Fertiliser tax appears to be efficient especially when combined to decoupling while explicit payments on nutrient surpluses as well as full decoupling have some negative side-effects.

Keywords— **Agri-environmental policies, nutrient surplus, agricultural sector modelling.**

I. INTRODUCTION

Water quality issues and biodiversity maintenance are among the top environmental concerns in European agri-environmental policy. Nitrate directive of the European Union and national legislation have raised up needs for detailed agri-environmental analyses at country and EU level. Biodiversity and climate change issues, including greenhouse gas (GHG) abatement in agriculture, have become common subject for economic analyses in agriculture. The main dilemma is how to decrease environmental damage caused by agriculture (eutrophication of surface waters, polluting groundwater, producing and decreasing biodiversity implying decreasing number of farmland birds, for example) and still response to increased demand and prices of agricultural products globally and in the EU. A major part of the recent upswing in the demand and prices of agricultural products is seen to be caused by growing demand of livestock products whose production has the relatively high potential to cause environmental damage. The main principle stressed in the recent CAP reforms is that agriculture should respond to changing market demand and prices, and production decisions should not be based on agricultural supports still dominating the CAP. Hence there is a challenge how to reach the environmental targets and still meet the growing demand.

Although the economic theory of agricultural nutrient pollution control is well developed there is quite a limited experience with actual implementation of the proposed policy instruments, such as fertilizer taxes or nutrient surplus instruments. Although fertilizer taxes (including both nitrogen and phosphorus based taxes) have been implemented in some OECD countries, those taxes have usually been levied at such a low rates that their impact on fertilizer use intensity has been quite moderate. Moreover, experience from nutrient surplus based instruments has been very limited to date. In fact, many OECD countries have mainly relied on voluntary agri-environmental payment programs to reduce agricultural nutrient runoff into watercourses. The obvious problem with these voluntary payment programs is that their environmental effectiveness may be significantly reduced by other, environmentally distorting agricultural policies. Policies coupled to production may provide strong incentives to increase input use intensity of environmentally harmful inputs, such as fertilizers or pesticides, or they may drive land allocation towards more intensive crops or expand agriculture into sensitive areas, i.e. such incentives may reinforce the environmental market failures. Conventional policy design principle is that these policy failures should be removed first and then the remaining market failures should be addressed by targeted policies.

In less favoured areas (LFAs) one of the main concerns is agricultural viability: How to maintain agricultural production in naturally disadvantaged areas in the on-going trends of market liberalisation and decoupling? In less favoured areas agriculture has also been seen as a rural “backbone” and important in order to maintain rural infrastructure.

Common Agricultural Policy (CAP) of the European Union includes payments for less favoured areas (LFA payments). They are paid in addition to CAP payments paid in all areas of production in the EU, in order to maintain agricultural production also in regions which are not otherwise competitive at equal basis. However the CAP reform implemented in 2005 – 2006 decoupled appr. 90% of payments from production decisions. From the viewpoint of maintaining production in less favoured areas the CAP reform increased the importance of LFA payments and other payments which are still more coupled to production than decoupled CAP payments. In addition to LFA payments there are also national payments in order to maintain agricultural production in most disadvantaged regions. National support schemes are important in Switzerland, Norway, Finland and northern part of Sweden. National payments typically include payments per hectare of certain crops, heads of certain animals, and explicit price support per litre of milk. Compared to decoupled CAP payments, which are paid if land is kept in good agricultural condition, the national payments are more coupled to production. Price supports influence not only production volume but also make the use of inputs more intensive. Hence such payments have a high risk of polluting environment.

In this paper our aim is to evaluate if any significant environmental damage can be avoided without risking maintenance agricultural production in less favoured areas. Our first goal is to evaluate if any policy measures reaching such possibly contradictory targets may exist. Our second goal is to evaluate if there is any policy measure, or a combination of two, that could promote several targets.

Next, we present our methodology. We analyse different policy options using an agricultural sector model. Then we present the results of our analysis which is made for Finnish agriculture, but there is no primary reason why the results could not be generalised to other less favoured areas with similar production structure and level of specialisation. Finally we draw four main conclusions.

II Methodology

A. Indicators of environmental impacts of agriculture

The soil surface nitrogen and phosphorus balances for each crop are calculated as the difference between the total quantity of nitrogen or phosphorus inputs entering the soil and the quantity of nitrogen or phosphorus outputs leaving the soil annually. The aggregate soil surface balances (surplus/deficit) for nitrogen and phosphorus per total agricultural land in each region in the model were calculated by adding the total nutrient content of fertilisers (summed over all crops), organic manure of all animals, and nitrogen depositions, and by subtracting the nutrient content of the harvest (summed over all crops) and losses to the atmosphere (5 kg N/ha). The calculated net nutrient surplus (kg/ha) provides an indicator of the production intensity, and of the potential nutrient losses and environmental damage to surface and ground waters.

For the sake of completeness two sets of nutrient balances were calculated:

1) for all available farmland no matter of use in order to monitor the aggregate change in the intensity of all farmland use;
2) for all farmland used in production (excluding set-aside and idled land) in order to monitor aggregate changes in active production area.

These two balances are necessary to avoid biased conclusions. For example, nutrient surpluses calculated for all farmland may decrease while nutrient surpluses for active production area may increase. In that case, the total nutrient runoff may even increase.

B. Policy options

Since the national supports and agri-environmental payments are very significant in Finland we focus on the different options of these supports, in combination with CAP payments and LFA payments which we assume unchanged in this analysis. Our options to be analysed are as follows:

The baseline scenario (BASE)

The on-going Common Agricultural Policy (CAP) reform scenario (from now on the REF scenario) follows the CAP reform agreement made in June 2003. From 2006, all CAP arable area payments became decoupled from production and a regionalised flat-rate payment was introduced in Finland for all farms and all crops (including set-aside, but excluding some permanent crops). However, 69% of bull premia and 100% of suckler cow premia remain coupled to production, i.e. paid per animal. On top of the CAP reform implemented in 2006 we assume that milk quotas are expanded 2% per year starting at 2008 which is assumed to result in a 15% reduction dairy product prices in the EU, averaged in producer price level, from 2006 level. However butter and skimmed milk prices is assumed to decrease relatively more than the prices of cheese and fresh products, suggested by a number of EU level studies (e.g. [1]). We do not assume any compensation for the price reduction due to milk quota expansion. However we assume prices of grain, meat and dairy products to remain clearly at a higher level than EU prices at 2001-2005, following the world market trends predicted by [2].

Full decoupling of national support and CAP beef premiums (DEC_ALL)

In this scenario, all agricultural supports and prices are kept the same as in the BASE scenario, but national supports paid per hectare and animal, or litre of milk, are decoupled from production and paid as a per hectare payment, no matter of production, as long as the land is kept in good agricultural condition. National price support for milk was €188 million, other animal linked support was €164 million, and hectare based support was €220 million in 2005. In total, national support amounted to €572 million in 2005 while the total of CAP payments was €524 million [3].

Tax on nitrogen fertiliser (FTAX)

In this scenario we assume a tax of 21 c/kg of nitrogen fertiliser, from year 2008. This means that the tax rate varies in different compound fertilisers, e.g. from 7% up to 40%, depending on the nitrogen content. The average tax rate is appr. 20%. The tax is not compensated to farmers.

Combined decoupling and fertiliser tax (DEC_ALL+FTAX)

Here we assume that both the fertilisation tax and decoupling national payments and the remaining CAP beef premiums, described above, are valid simultaneously.

Payments on decreased nutrient surplus (BAL)

In this scenario, it is assumed that from 2008 a farmer is paid full amount of agri-environmental support (€100/ha) only if he/she decreases both nitrogen and phosphorus surpluses by 50% from the 1995 level. In other words, decreasing the nitrogen surplus by 50% brings €50 per hectare of all farmland regardless of production, and decreasing the phosphorus surplus by another 50% brings another €50 per hectare of land regardless of production. This means that a major income drop may take place if nutrient surpluses are not reduced significantly in the period 1995–2008. For example, if the reduction is 30% in both nitrogen and phosphorus surplus, a farmer receives agri-environmental support of €60 /ha. All other supports and prices are kept at BASE scenario level.

C. Sector model used in economic analysis of policy options

The relationship between nutrient surpluses, biodiversity, agricultural production and farm income is more complex than merely analysing individual farm or crop level management practices. Changes in agricultural production may be linked to production specialisation, technological change and market feedback through prices. Partial analyses focusing on individual production lines, which compete on the same regional land and labour resource, may not always provide a sound basis for policy recommendations. A sector level analysis, entailing the overall change in agriculture, is needed when evaluating potential to reduce nutrient runoff from agricultural sector. We examine the policy options by simulating their production impacts using a dynamic regional sector model of Finnish agriculture (DREMFIA) (for a description of the model see [4], [5]). In addition to analyses of production and income effects of agricultural policies, this model has been earlier employed to assess the effects of alternative EU level policy scenarios on the multifunctional role of Finnish agriculture and on the explicit water quality through integrated modelling studies (e.g. [6]).

DREMFIA is a dynamic recursive model which simulates rational economic behaviour and the effects of various agricultural policies on land use, animal production, farm investment and farmers' income. The model consists of two major parts:

(1) a technology diffusion model which determines sector level investments in different production technologies, and
(2) an optimisation routine which simulates annual production decisions (within the limits of fixed factors) and price changes, i.e., supply and demand reactions, by maximising producer and consumer surpluses subject to regional product balance and resource (land and capital) constraints.

The optimisation model is a typical spatial price equilibrium model (see e.g. [7]), except that no explicit supply functions are specified (i.e. supply is a primal specification). Furthermore, foreign trade activities specific to 4 main regions are included in DREMFIA. The Armington assumption [8], which is a common feature in international agricultural trade models but less common in one-country sector models, is used. Imported and domestic products are imperfect substitutes, i.e., endogenous prices of domestic and imported products are dependent. There are 18 different processed milk products and their regional processing activities in the model. Milk fat, protein and casein are used in production in 18 different dairy products.

Four main areas are included in the model: Southern Finland, Central Finland, Ostrobothnia (the western part of Finland), and Northern Finland. Production in these is further divided into sub-regions on the basis of the support areas. In total, there are 18 different production regions. This allows a regionally disaggregated description of policy measures and production technology. The final and intermediate products move between the main areas at certain transportation cost.

Technical change and investments, which imply evolution of farm size distribution, are modelled as a process of technology diffusion. The simulated change in farm size structure is validated to official statistics. Investments depend on economic conditions such as interest rates, price changes, support payments, production quotas, and other measures imposed on farmers. Investments and depreciations may lead to regional concentration of production.

The use of variable inputs, such as fertilisers and feed stuffs, is dependent on agricultural product prices and fertiliser prices through production functions. The nutrients from animal manure are explicitly taken into account in the economic model. Feeding of animals may change provided that nutrition requirements, such as energy, protein, phosphorous and roughage needs, are fulfilled. In the feasible range of inputs per animal, production functions model the dependency between the average milk yield of dairy cows and the amount of concentrates and other grain based feed stuffs.

The crop level of the different crops is determined separately for each year and for the 18 production regions. The crop levels are obtained by determining the optimum fertilisation at the farm level using equation (1).

$$\frac{dF(N)}{dN} = \frac{P_f}{P_c} \quad (1)$$

$F(N)$ is the fertilisation response function in terms of nitrogen, P_f is the price of nitrogen, and P_c the price of the crop product. Crop prices P_c may be expected prices, intervention prices or market prices of the previous year. As the fertilisation response function, the Mitscherlich function

$$F_m(N) = m(1 - ke^{-bN}) \quad (2)$$

where F is yield per hectare, N is nitrogen use per hectare and m, k and b are the parameters, is used for barley, malting barley, wheat, oats, mixed cereals and peas.

The quadratic function (3) is used for rye, potatoes, sugar beet, hay, silage, green fodder and oilseeds.

$$F_q(N) = a + bN + cN^2 \quad (3)$$

For cereals the Mitscherlich function was preferred to quadratic function since the quadratic function results to rather small changes in the nitrogen fertilisation and crop yield levels even in the case of large changes in the price relation between the fertiliser price and crop price. Hence the changes in crop yield level due to minor and temporary price shocks are almost negligible, according to the crop response functions used in this study. However, together with the concavity of the crop response functions, the increasing energy and fertiliser prices and decreasing prices of crops, as observed in period 2000-2005, are likely to result in relatively larger reductions in the crop yield levels. For example, introducing a 20% nitrogen fertiliser tax in the ftax-scenario decreases nitrogen fertilisation level by 5-15%, and the crop yield levels by 2-4%.

Milk quotas, which constrain milk production at farm and country level, are traded within three separate areas in the model. Within each quota trade area, the sum of quotas purchased must equal the sum of quotas sold. The price of the quota is the weighted sum of the shadow values of an explicit quota constraint in each sub-region. Milk quota trade results in increasing production efficiency. The observed milk quota prices have served a valuable reference in the model validation.

The overall model replicates very closely production development in 1995–2005. Official agricultural production and price statistics (http://matilda.mmm.fi) have been used as the basis in validation. Price changes in 1995–2005 have been validated through calibrating the unobserved parameters in the Armington system and in export cost specification. The model is built to reach the steady-state equilibrium, in terms of production volume and regional location of production, in a 10–15 year period given no further policy changes.

What is important is that all the policy options listed above are carefully implemented in the DREMFIA model utilising its structure. Policy options BASE and DEC_ALL including decoupling are relatively straightforward to implement since decoupling reduces payments per animal, litre of milk and hectares of specific crops, and this volume of support is shifted farmland. Fertilisation tax is easy to implement by adding tax rate on commercial fertilisers on the basis of their nitrogen content. However the fertiliser tax (FTAX option) implemented in the DREMFIA model means that feed crops gain an additional relative advantage of fertiliser tax in regions abundant with animal production and manure. The BAL scenario, where decreasing nitrogen and phosphorous balances are required, is implemented in DREMFIA by adding the nutrient balance terms, and payments on reduced balances subject to the reference year, directly in the objective function. Such implementation changes the structure of DREMFIA and results in changing spatial structure and volume of production. In other words, BAL scenario requires a rigorous microeconomic treatment taken into account changing relative profitabilities between production lines and regions. This is why the regionally disaggregated sector model is used in this study.

III RESULTS

Dairy and beef production constitute appr. 50% of the value of agricultural production in Finland. Rapid expansion of milk quotas and resulting decline in milk producer prices seems to be a challenge for Finnish milk sector in the baseline. However the production level recovers gradually after 10-15% reduction due to structural change due and expansion of large dairy farms. Finally the production level stabilises at 5% level below the 2006 production (Fig. 1). Cheese and butter exports decrease while dairy product imports increase only moderately in the baseline, despite the milk quota abolition at the EU scale.

However the milk and beef production, as well as their recovery and stabilisation in the baseline, is dependent on national subsidies paid in Finland. Decoupling national and CAP beef premia from production results in a rapid decline of production to a level where production covers only domestic consumption of liquid milk, most other fresh dairy products and some part of cheese production. Decoupling CAP beef premiums and all national support from production provides an incentive to decrease milk and meat production and increase grain or set-aside area. Since many farms are small and production costs grain are high in Finland, most dairy farmers who exit milk production make the minimum effort to receive decoupled payments, i.e., they leave their land as set-aside instead of cultivating cereals on former grasslands which has been the trend in 1995–2005 (Figs 2-3). Hence it seems that this distortion created by former CAP payments on cereals is to be resolved by CAP reform, but high grain prices predicted by [2] may increase the grain area again, if not reversed by further decoupling or fertiliser tax.

Alternative policy scenarios BAL and FTAX, on top of the BASE scenario, however, have a minimal impact on aggregate milk production volume in Finland (Fig. 1). It is interesting that the BAL scenario results in slightly higher milk production. This is because milk production requires roughage production and is thus relatively more extensive by nature than pork and poultry production which are already regionally concentrated in South-West Finland. Hence, it is relatively cheaper to extend milk production than pork production, and hence BAL and FTAX provide a slight relative advantage to milk and beef production. Consequently, pork production decreases appr. 20% below the BASE scenario level in the BAL and FTAX scenarios until 2020.

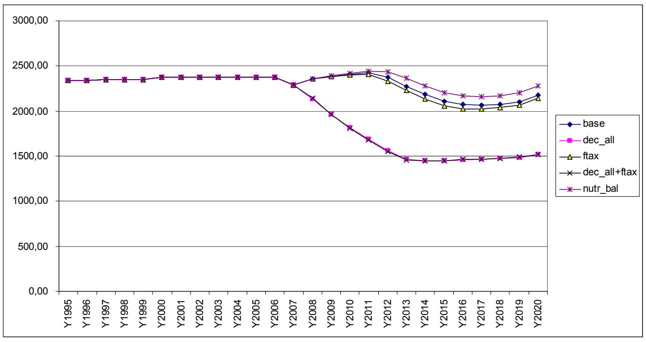

Figure 1. Milk production volume (million litres).

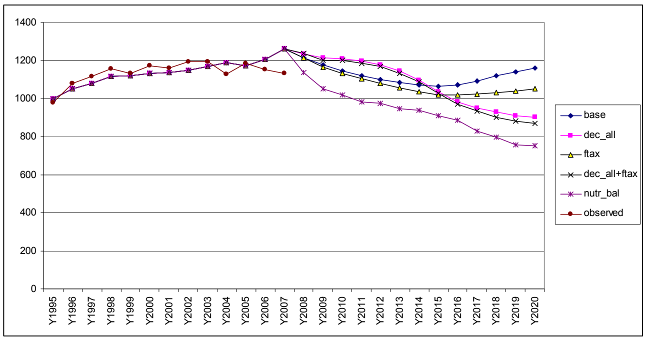

Figure 2. Area under cereals cultivation (1000 ha).

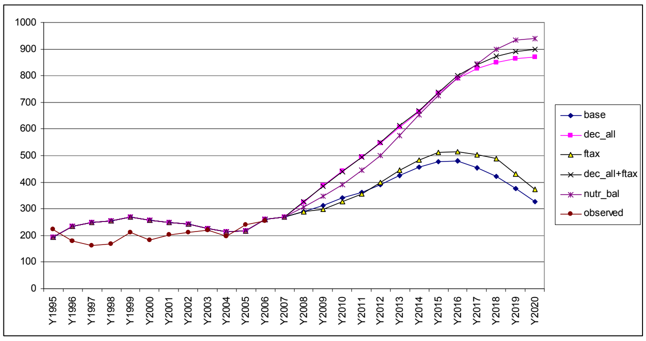

Figure 3. Area under cereals set-aside (1000 ha).

Nevertheless, beef production decreases clearly below the BASE scenario level in the BAL scenario. Farms specialised in beef production aiming to reach economies of scale, and which have grown at a rapid rate in recent years, face considerable economic costs of increasing nutrient balances in BAL scenario.

However while the BAL option results in a similar drop in nitrogen balance (Figs 4-5) as decoupling scenario (DEC_ALL) it results in a much higher set-aside area and very low grain area. Consequently, phosphorous surplus on cultivated area (Fig. 6) is higher in BAL scenario, as well as in decoupling scenario, compared BASE. This is due to the fact that decreasing phosphorous balance is relatively more expensive than reducing nitrogen balance. Hence scenario DEC_ALL and BAL result in large set-aside area and intensive livestock production on competitive regions. Large set-aside area promotes biodiversity if managed in extensive way without annual tillage. Such green vegetated set-aside seems likely due to low use of labour and due to the national policy decision that any uncultivated land is eligible for CAP payments only if established as grasslands.

Impact of decoupling national payments on farm income is positive despite the large reduction in animal production. This result is however conditional on the assumption that decoupled payments remain and are not directed to other purposes. The downside of the decoupled payments paid for farmland is that they accumulated to land prices and make it costly for animal farms to expand production and acquire more land in order to spread manure according to environmental standards and requirements of existing agri-environmental support scheme. Furthermore the increasing payments for land increase the relative profitability of activities and products which use farmland as a significant input. Hence increasing payments on farmland may further increase cereals area in current very positive cereals price prospects (updated by [8]), not fully taken into account in this study. In terms of agricultural viability it is questionable if Finnish agriculture should be directed to cereals production and set-aside through area payments instead of animal production where low crop yield level and other natural disadvantages play a relatively smaller role than in cereals production. High area payments promoting part-time cereals cultivation have already resulted in decreasing productivity development in Finnish agriculture [9, p. 60]. Such development may not benefit environment in the long run.

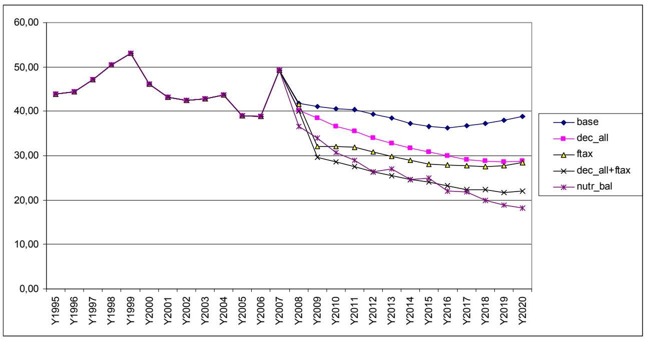

Figure 4. Nitrogen surplus on all farmland (kg/ha).

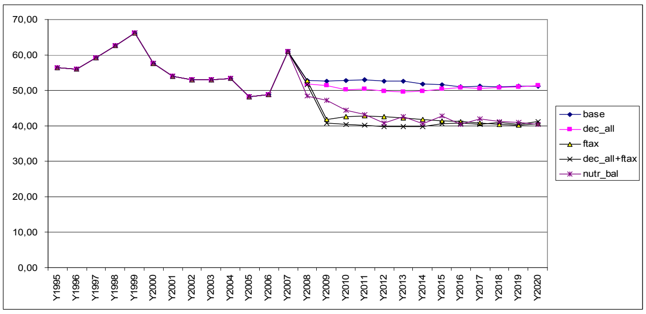

Figure 5. Nitrogen surplus on cultivated land (excluding set-aside) (kg/ha).

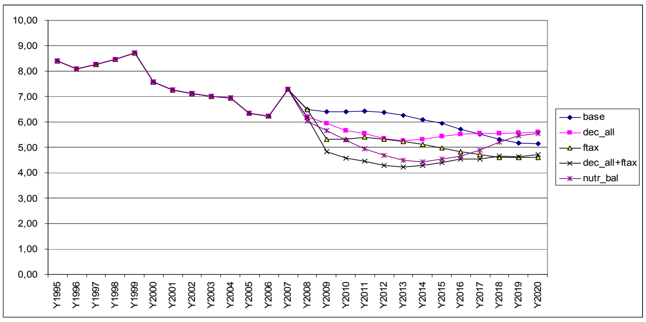

Figure 6. Phosphorous surplus on cultivated area (kg/ha).

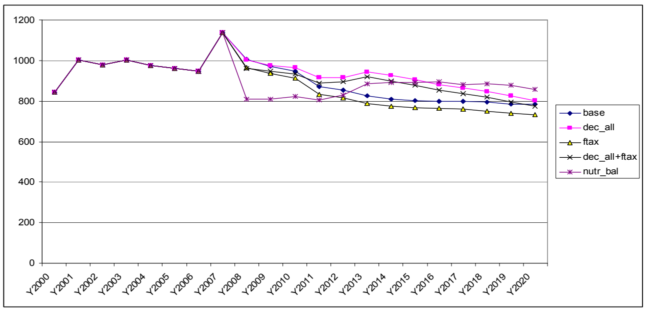

Figure 7. Farm income (million euros).

Imposing fertiliser tax (FTAX) and paying environmental support solely on the basis nutrient balance reductions (BAL) lead to clearly decreasing farm income in the short run (Fig. 7). The income loss gradually decreases and vanishes in the case of BAL policy option when set-aside increases very significantly at the expense of cereals cultivation and pork and poultry production. However the fertiliser tax results in a permanent loss of farm income by 50-70 million euros (appr. 5 %). The costs and benefits of these policy options, and some other options such as explicit payments on biodiversity indices, have been analysed by [10]. The relevant result here is however that fertiliser tax decreases the use of chemical fertilisers and provides incentives for more efficient utilisation of animal manure, without significant distortions on land use and animal production simulated in the case of BAL scenario. FTAX option avoids decreasing milk and beef production based on grasslands. If desired, the income loss caused by fertiliser tax can be compensated by lump sum decoupled payments, provided that the compensation is not correlated with fertiliser use on individual farms.

IV CONCLUSIONS

This study provides four major conclusions. First, we accept the conventional wisdom that at least the most significant production linked policy measures should be first abolished, or decoupled from production, before introduction of more targeted agri-environmental policy measures provides significant reduction in negative environmental impacts of agriculture. We can see from the results that decoupling production linked animals support already provides a substantial reduction in nitrogen and phosphorous balances. Decoupling reduces both overall production as well as use of inputs, such as use of concentrate feed per animal, and thus decreases nutrient surplus. Since production costs are higher than market revenues – which is common not only in Finland but also in other less favoured areas, agricultural income is slightly increased due to decoupling. Simultaneous introduction of fertiliser tax, on the top of decoupling national and CAP beef premia, decreased nitrogen surpluses almost by 50% from the baseline in our simulation.

Second, full decoupling of all production linked payments are very likely to result in a significant decrease of production in less favoured areas and concentration of production to relatively more competitive regions inside a country. This may result in increasing nutrient balances on some regions indicated by the non-decreasing nutrient balances on actively cultivated area.

Third, decreasing negative environmental impacts of agriculture through decoupling may provide additional benefits on farmland biodiversity, if extensive grassland cultivation (as a low-cost option for set-aside management) is promoted through payment criteria or small bonus for farmers. In less favoured areas even a small bonus for farmers may keep land on grassland set-aside instead of grain since grain production costs are still high compared to the cereals prices.

Fourth, fertiliser tax seems to be a relevant policy tool since recently increased grain prices may increase chemical fertilisation and nutrient balances. Furthermore, fertiliser tax has a relatively small negative impact on animal production, especially on milk and beef production which may even gain competitive advantage over pork and poultry dependent on grain based feeds often cultivated using purchased chemical inputs. Hence fertiliser tax could be an efficient targeted tool combined with partial decoupling of production linked support. An appropriate combination of decoupling and fertiliser tax could be an option capable of reaching many targets, or at least in finding Pareto-efficient frontier in the space of contradictory agri-environmental targets in less favoured areas.

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